The "RED versus NIR" Plane to Retrieve Broken-Cloud Optical Depth from Ground-Based Measurements

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ABSTRACT

A new method for retrieving cloud optical depth from ground-based measurements of zenith radiance in the red (RED) and near-infrared (NIR) spectral regions is introduced. Because zenith radiance does not have a one-to-one relationship with optical depth, it is absolutely impossible to use a monochromatic retrieval. On the other side, algebraic combinations of spectral radiances, such as normalized difference cloud index (NDCI), while largely removing nonuniqueness and the radiative effects of cloud inhomogeneity, can result in poor retrievals due to its insensitivity to cloud fraction. Instead, both RED and NIR radiances as points on the "RED versus NIR" plane are proposed to be used for retrieval. The proposed retrieval method is applied to Cimel measurements at the Atmospheric Radiation Measurements (ARM) site in Oklahoma. Cimel, a multichannel sun photometer, is a part of the Aerosol Robotic Network (AERONET)—a ground-based network for monitoring aerosol optical properties. The results of retrieval are compared with the ones from microwave radiometer (MWR) and multifilter rotating shadowband radiometer (MFRSR) located next to Cimel at the ARM site. In addition, the performance of the retrieval method is assessed using a fractal model of cloud inhomogeneity and broken cloudiness. The preliminary results look very promising both theoretically and from measurements.

1. Introduction

The most common approach for retrieving cloud optical depth from ground-based observations uses downwelling fluxes measured by pyranometers in the 0.3- to 3.0-μm region of the solar spectrum (Leontieva and Stamnes 1994; Boers 1997). They are relatively cheap and included as standard equipment at many meteorological stations. In addition to broadband pyranometers, there are multifilter rotating shadowband radiometers (MFRSRs) that infer the optical properties of clouds using downwelling fluxes measured at one or at several wavelengths in the visible and/or near-infrared spectral regions (Min and Harrison 1996; Leontieva and Stamnes 1996). The key element in both retrieval techniques is the one-to-one mapping of the "observed" fluxes into cloud optical depth through (the use of) plane-parallel radiative transfer. Both methods are expected to work well only for completely overcast clouds (Ricchiazzi et al. 1995; Dong et al. 1997), giving an *effective* optical depth for the whole sky since, for inhomogeneous clouds, each sky element contributes to the downwelling flux differently (Boers et al. 2000). To infer cloud optical depth locally, one can assume to use a narrow-field-of-view radiometer that measures radiances instead of fluxes (Pavloski and Ackerman 1999). However, lack of one-to-one relationships between radiance and cloud optical depth (e.g., see Fig. 1 in Barker and Marshak 2001 for zenith radiances) prevents the direct use of radiances also.

Recently, Marshak et al. (2000) and Knyazikhin and Marshak (2000) proposed to exploit the sharp spectral contrast in vegetated surface reflectance across 0.7-μm wavelength to retrieve cloud properties from ground-

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